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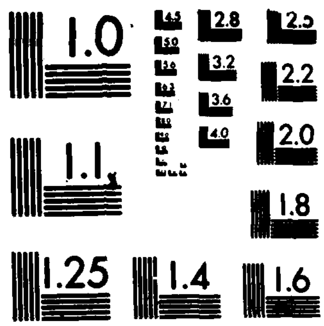

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FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

USING GAS-TURBINE POWER STATIONS WITH AIRCRAFT ENGINES FOR POWER-AND-HEAT GENERATION

by

A. A. Margaryan

FOREIGN TECHNOLOGY DIVISION

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U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*<u>ye</u> initially, after vowels, and after ъ, ь; <u>e</u> elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

GRAPHICS DISCLAIMER

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USING GAS-TURBINE POWER STATIONS WITH AIRCRAFT ENGINES FOR POWER-AND-HEAT GENERATION

A. A. Margaryan, Engineer

The first experimental model of a power station using aircraft engines (the AI-20 turboprop engine used on IL-18 aircraft) was created in the Soviet Union in 1965. Subsequently, mobile power stations with power of 1.2-1.6 MW were created using the AI-20 and AI-20K.

At the same time, investigations into the use of more powerful turboprop and turbojet engines: the RD-3M-500, NK-12-MV, D-30, etc. - were being started up in different planning and design organizations (Promenergoproyekt [State All-Union Planning Institute for Planning the Construction of Industrial Heat and Electric Power Plants for Supplying Power to Industrial Establishments in All Branches of the National Economy], Teploelektroproyekt [All-Union State Planning Institute on the Design of Electrical Equipment for Heat Engineering Installations], VTI [All-Union Institute of Heat Engineering]). The first of the above engines is the most inexpensive and most powerful. Primarily these engines are used today for creating GTU [gas-turbine power units].

Planning work on the creation of an experimental industrial gas-turbine power station in the territory of the Kazan' TETs-3 [thermoelectric power plant] was carried out at the Promenergoproyekt institute in 1968. The engine RD-3M-500 with a specially designed power

turbine with power of 18 MW is the main thermomechanical equipment of the power plant. Three versions of the gas-turbine power station were considered:

1. The installation of two assemblies with power of 18 MW each, consisting of gas-generator aircraft engine RD-3M-500 placed coaxially with the power turbine, and electrical generator TVS-30.

2. The installation of one assembly with power of 36 MW, consisting of two gas generators placed perpendicular to two power turbines (the latter are placed on the same shaft as electrical generator TVS-30).

3. The installation of one assembly with power of 54 MW, consisting of three gas generators located perpendicular to three power turbines (the latter are placed on the same shaft as electrical generator TVF-60).

The Scientific-Technical Council of the Ministry of Power Engineering and Electrification USSR confirmed the third version of the GTU for construction as the experimental industrial installation.

Besides creating a definite source of peak power in power systems, the GTU can also be used as a source for heat generation because of the high temperature of the exhaust gases.

The purpose of this study is to determine certain power engineering (power-and-heat generation) indices of GTU based on RD-3M-500 aircraft engines and to show the possibility of using them for generating power and heat.

Figure 1 shows a schematic diagram of GTU-18 with one RD-3M-500 engine in combination with a heating-system water heat-utilization heater. The GTU-18 has the following main (calculated) characteristics: gas temperature and pressure in front of engine turbine: 727°C and 6 kg/cm^2, respectively; air flow rate: 149 kg/s; fuel flow rate: 2.93 kg/s; exhaust gas temperature: 403°C; power on electrical generator

terminals: 18 MW, efficiency of assembly: 21% [1].

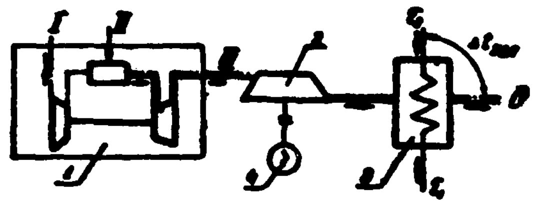

Fig. 1. Schematic diagram of GTU-18. 1 - turbojet engine RD-3M-500; 2 - power turbine; 3 - heating-system water heater; 4 - electrical generator. I - air; II - fuel; III - gas; IV - to the atmosphere.

It should be pointed out that the ambient air parameters have a great effect on the operation of the GTU. Thus, when the temperature of the ambient air changes from +35 to -40°C (if the initial gas temperature is held constant), the power of a single-compressor GTU with a power TND [low-pressure turbine] can increase 1.8-fold.

The heat-and-power generating capabilities of the GTU are invesitgated using the characteristics of the compressor and turbine or the entire installation, also including the power turbine. In our investigations, we used the universal characteristics of a single-compressor GTU with a power TND [2] corresponding to the operation of a turbojet engine in which the jet nozzle is replaced by a specially made power turbine.

Limiting ourselves to the calculation of the installation under variable conditions at the design parameters of the atmospheric air (or with these data being available), the use of these characteristics makes it possible to cover all conditions at any values of the pressure and temperature of the external air.

Having the calculated values of the GTU (the gas and fuel flow rate, the power on the electrical generator terminals) at the design parameters of the external air (t_H = +5°C and p_H = 760 mm Hg), and without special errors, assuming that the air pressure is constant, we find the dependence of the power and gas and fuel flow rates on the temperature of the ambient air (Fig. 2).

The power-and-heat generating capability of a GTU with one RD-3M-500 engine is determined from the formula:

$$Q=G_r c_r (t'_r - t''_r) \cdot 3600, \quad \text{Gcal/h},$$

where G_r - the gas flow rate (of the installation) through the heating-system water, kg/s; t'_r - the gas temperature (after the power turbine) during the admission of heating-system water into the heater, °C; at the design parameters: t'_r = 403°C; t''_r - the gas temperature at the outlet from the heating-system water heater, °C; c_r - the heat capacity of the gases, kcal/kg°C; at t'_r = 403°C, it is assumed that c_r = 0.26 kcal/kg°C.

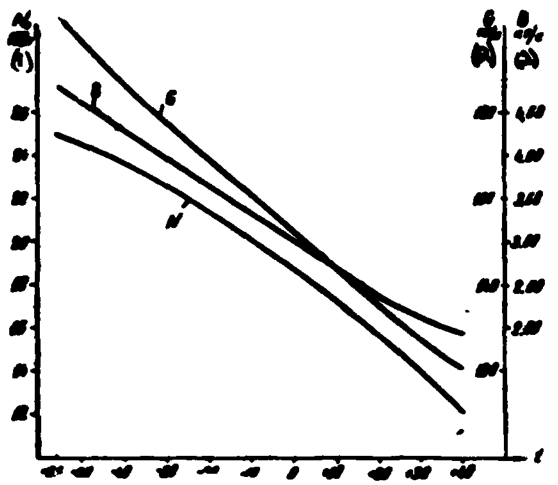

Fig. 2. Dependences of power, gas and fuel flow rates of GTU-18 on external temperature.
KEY: (1) MW. (2) kg/s.

In the formula, the value t'_r is assumed to be constant, since the gas temperature in front of the engine turbine is limited by its value in the nominal conditions: 727°C. The variables in the formula are the gas flow rate G_r and the gas temperature at the outlet of the heater t''_r. The gas flow rate depends on the external air temperature (Fig. 2), and the gas temperature after the heater outlet - on the temperature of the circulating heating-system water τ_2. The latter, in turn, depends on the external air temperature state (at high external air temperatures, the heat release to the external users depends on the hot water supply flow rate). Therefore, the power-and-heat generation capacity of the GTU is a variable value from the annual standpoint, and it depends on the external air temperature.

The heating-system water heater of the main power-and-heat generation gas-turbine installation GT-25-700-1 LZM installed at the Kiev TETs-2 can be used as the heat exchanger for utilizing the exhaust gas heat.

If the temperature head on the "cold" end of the heating-system

water heater $\Delta t_{зол} = t''_r - \tau_s$ (Fig. 1) is considered to be constant and equal to $\Delta t_{зол} = 30°C$ (economically justified limits of 20-40°C) [3], we can obtain the value of the power-and-heat generation capacity of a GTU with one RD-3M-500 engine for any climatic region. For the climatic conditions of Yakutsk, Moscow and Yerevan, the change in Q from the external air temperature is shown on the combined heat consumption graph at a power-and-heat generation factor of $a_{ГТУ}$ = 0.5 (Fig. 3). The areas under curves I, II and III show the annual heat output from the GTU. The absolute values of the heat generated by the installation at the design temperatures of the ambient air $t_{н.р.}$, obtained for the conditions of the above cities are: Yakutsk: $Q_{ГТУ}$ = 57.5; Moscow: $Q_{ГТУ}$ = 49.0; and Yerevan: $Q_{ГТУ}$ = 45.0 Gcal/h.

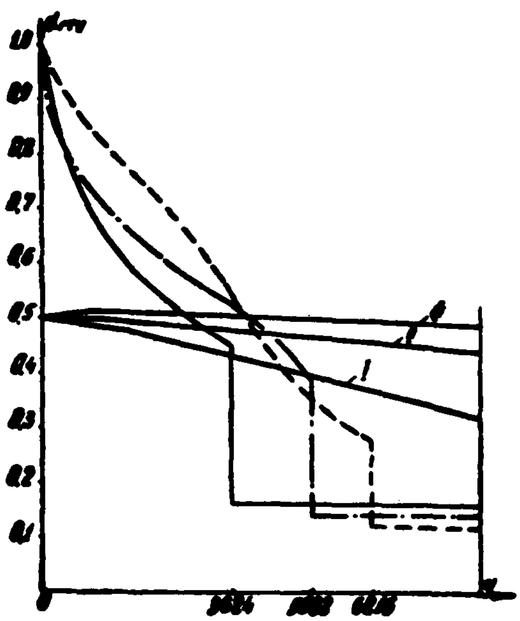

Fig. 3. Annual curves of heat consumption for climatic conditions of the cities Yakutsk (- - -), Moscow (- • -), and Yereven (———).
I, II, III - power-and-heat generating capacities of GTU-18.

Because of the heat of the gases from the installation, by changing the heating-system water flow rate, we can heat it to the desired temperature without increasing the consumption of engine fuel. In our calculations, with the design temperature of the ambient air, the temperature of the feed heating-system water is considered to be $\tau_1 = 130°C$, which is far from the upper limit (the heating-system water can also be heated to 170-200°C). Therefore, the conditions of heat output make it possible to considerably decrease the heating-system water flow rate at this station compared to that of a steam-turbine TETs [steam power plant] [4].

It is possible to create more powerful GTU for power generation based on the RD-3M-500 turbojet engine. Obviously, a gas-turbine power station consisting of several turbojet engines (e.g., GTU-54

or GTU-108) can provide three and six times as much heat as one installation.

Conclusions

1. When aircraft engines are used in power engineering as peak power and stand-by installations, rather high-temperature exhaust gases are ejected into the atmosphere. The heat of the exhaust gases can be used for the purpose of power-and-heat generation by installing a heat-utilization heater for the heating-system water at the GTU.

2. The power-and-heat generating capacity of a GTU with one RD-3M-500 engine depends on the quantity of gases and the degree of their cooling, being on the order of 30-50 Gcal/h, depending on the climatic conditions.

3. GTU based on TRD [turbojet engine] can be used for the generation of power and heat in regions and cities located far away from large power sources and with limited water and fuel supplies.

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